A New Freshmen Engineering Design Experience in Chemical Engineering at NJIT

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Introduction

There is a general recognition of the need to give their students considerable training beyond the standard knowledge of a particular engineering field[i]. Students must now have the ability to think critically and communicate effectively, to work in multidisciplinary teams and have good interpersonal skills, and to exhibit a broader professional and ethical responsibility to society and the environment. These abilities are contained within the program outcomes of ABET[ii].

Undergraduate engineering programs now typically include a freshman design experience. There are a number of models[iii]. Some examples of such courses are listed here. At Northern Arizona University, students are introduced to current design software such as CAD, equation solvers, and spreadsheets. At Drexel University, the course focuses on the design process and its applications in engineering through a series of lectures and projects. There are also linkages to freshmen humanities courses. At the University of Wisconsin at Madison, students work in teams to determine customer needs, propose solutions, and design and test final products.

The freshmen and transfer students entering the New Jersey Institute of Technology (NJIT) continue to contribute to the considerable diversity of our student population. Historically, many of our engineering students are the first members of their families to enter college. Many are the sons and daughters of immigrants. As a result, most of our graduates enter the professional workforce upon graduation. Within the Otto York Department of Chemical Engineering (ChE) at NJIT, our freshmen fundamentals in engineering design (FED) experience is designed to appeal to a broad range of abilities – both mechanical and computational.

All engineering freshmen and transfer – those without a prior equivalent introductory design experience – students entering NJIT are required to take the FED course. Each engineering department offers its own FED course. This allows declared freshmen – the vast majority – to take the FED course of their home departments. Undeclared freshmen are assigned to an FED course with available space.

In this paper, we will describe the current FED course in the ChE department. The course activities will be described, as well as the assessment tools utilized. In addition, there will be a short discussion of a variation of the FED course now being tested for transfer students who are older and generally more experienced than the freshmen.

First-Day Surveys

One important assessment on the first day of the ChE FED course is a student survey shown in Figure 1. The questions deal with the students' background with popular software as well as their mechanical experiences prior to arriving at NJIT. All of the software and mechanical skills mentioned in the questionnaire are put to use in this course. The results provide guidance as to

Figure 1: First-day student survey

FED (ChE) Survey of Student Backgroun

Please answer the following questions honestly. answers will help me to try to provide you with a better course this term. Don't be embarrassed; your responses will be kept private

Scale (0 to 5): 0 = none, 5 = a lot

Computer

What is your general experience with Microsoft Word? ______

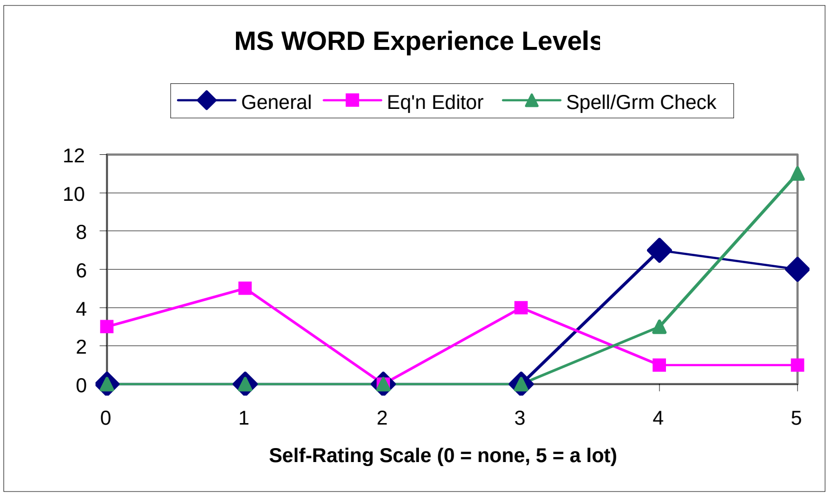
+ Using the equation editor in Word? __
+ Using the grammar and spell check in Word? ______

What is your general experience with Microsoft Excel?

some student capabilities as they enter the course, thus allowing us to specifically tailor the course content as the semester proceeds.

Incoming FED students have varied mechanical and computer experience levels, though there are some items in common. Figure 2 shows sample results for one question from the survey. For example, while the students are familiar with the basics operations of popular software packages, they are less experienced with more complex functions. For example, while the new students might know how to make a graph using Microsoft Excel®, they are less familiar with how to add a trend line and perform a regression analysis of the data, or how to perform spreadsheet calculations. While they know how to prepare a Microsoft Word® document, they are not likely to know how to properly write equations using Microsoft Equation 3.0®.

Figure 2: Sample results from First-Day Survey



Course Objectives and Structure

The overall objective of our ChE FED course is to give freshman and transfer students an introductory engineering design experience combining experimental and computational tools that is ***FUN!*** Specifically, the students will learn to work successfully in a team; to plan effectively; to design, engineer, and construct a working system that uses available resources, meets required objectives, and operates within stated constraints; and, finally, to report on their results.

The chemical engineering FED course meets three hours per week for fourteen weeks (one semester). It is divided into laboratory and computer components. Each week, the students typically spend 1-2 hours working in the laboratory, with the remaining time devoted to the computer software instruction. A graduate student teaching assistant helps the students in the lab and typically provides the instruction in the computer software in a dedicated department PC facility.

In the lab, students working in pairs design and construct a complex, bench-scale piping system that mimics a pilot scale air/water packed tower system used in our capstone unit operations laboratory. This challenge introduces the notion of scale to the students. The groups are provided with only a very general schematic, along with guidelines, objectives, and constraints. The construction and operation of the systems occur throughout the entire semester.

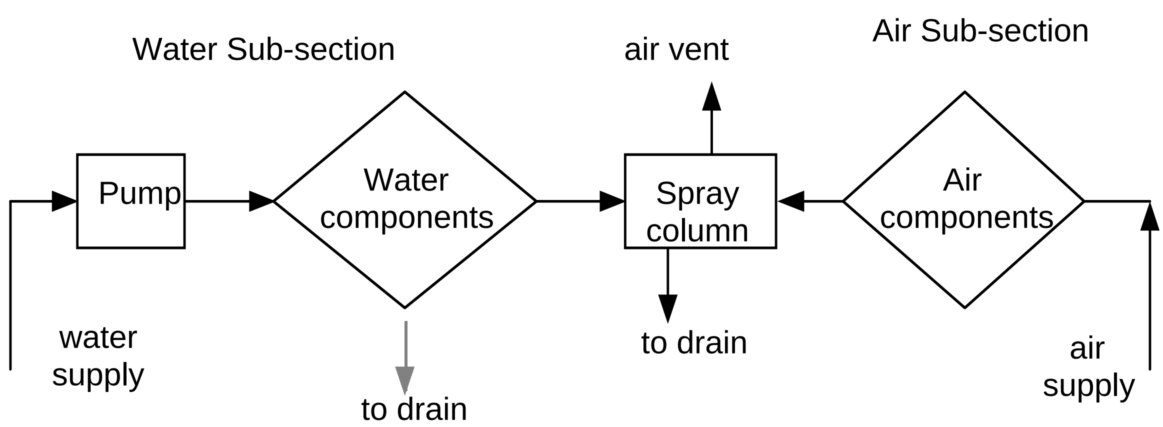
The computer component of the course extends the students' basic skills with common software packages by presenting tasks tied to their apparatus. For example, in modeling pressure drop data collected for their wet and dry packed pipes, the students learn an equation editor and how to do a trend line with statistics. The course culminates with a computer slide show oral presentation by each group.

Laboratory Experience – The Design Project

The students are given a general schematic layout (see Figure 3) showing, in very general terms, a piping system. The system consists of water and air subsections that intersect in a spray column. This is the only schematic provided to the students. They are then given a list of constraints for each subsection. For example, the air subsection must contain a 3-foot long section of 1" plastic PVC pipe filled with small plastic nylon pellets with a pressure gauge mounted on each end. The location of this packed pipe, to be used for a pressure drop as a function of air flow rate experiment, is not specified. The students are also shown bins of available supplies such as pressure gauges, valves, flow meters, and various pipe fittings.

The students mount their piping systems onto a grid of ½" aluminum rods built onto a centrally located low laboratory bench. The components are suspended with disposable plastic tie-wraps. In order to accommodate the increasing number of freshmen and transfer students needing FED, we have expanded the bench. The bench contains periodically-located stations with water and compressed air spigots, as well as electrical outlets and water drains. The water and air pressures are centrally regulated. Each group is given a set of hand tools. Bins in the room contain available components for building the layouts.

Figure 3: General schematic given to students the first day of ChE FED class



The students can design the system as they wish, as long as the constraints are met using only the available components. The constructed layouts must have water and air lines feeding a packed spray tower. Each line contains numerous components that provide a variety of construction challenges. Individual subsystems, such as packed pipes, provide opportunities for data collection and first-principle modeling, as well as calibration. The components are nearly all of threaded rigid plastic PVC, thus allowing for easy system fabrication and disassembly. Students are introduced to different types of seals, such as pipe threads and compression fittings.

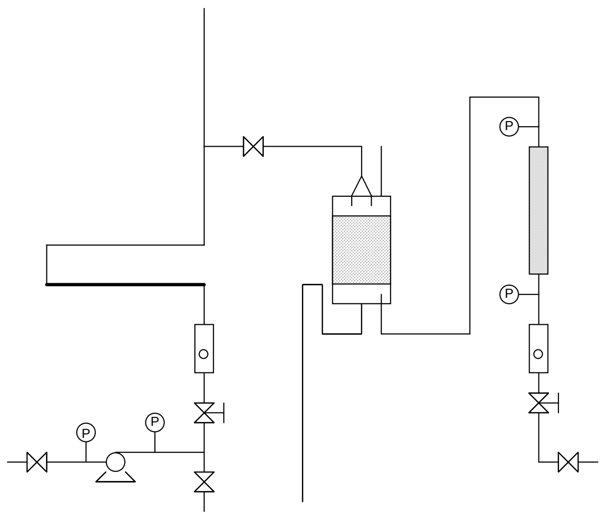
Using Microsoft Visio®, each student group must submit and obtain instructor approval for a detailed system layout, or process flow diagram (PFD). Some alterations of the initial design might result as the term progresses due to difficulties encountered by the students during construction, for example, scarcity of space and materials. Figure 4 shows an example of a final PFD.

Construction is generally completed by about the 10th week of the term. The remaining laboratory time is spent running several data collection and modeling exercises.

Computer Experience

The computer experience provides students with an introductory exposure to several programs useful in this course, as well as in their future. First-day survey data shows that the students are familiar with basic operations of Microsoft Word®, Microsoft Excel®, and Microsoft PowerPoint®. These basics are reinforced, while quickly moving into more advanced topics needed for this class. For example, students

Figure 4: Example flow system constructed by an FED student team



learn to how use the Microsoft Equation 3.0® option in Microsoft Word®, how to create a trend line and analyze the regression results as well as how to do basic calculations in Microsoft Excel®, and how to import items such as graphs and equations into Microsoft PowerPoint®. The survey, however, shows that almost none of the students have any experience with Microsoft Visio®. Therefore, this package must be introduced assuming no prior background.

During the semester, the four software packages are needed in required exercises that are tied to specific laboratory tasks:

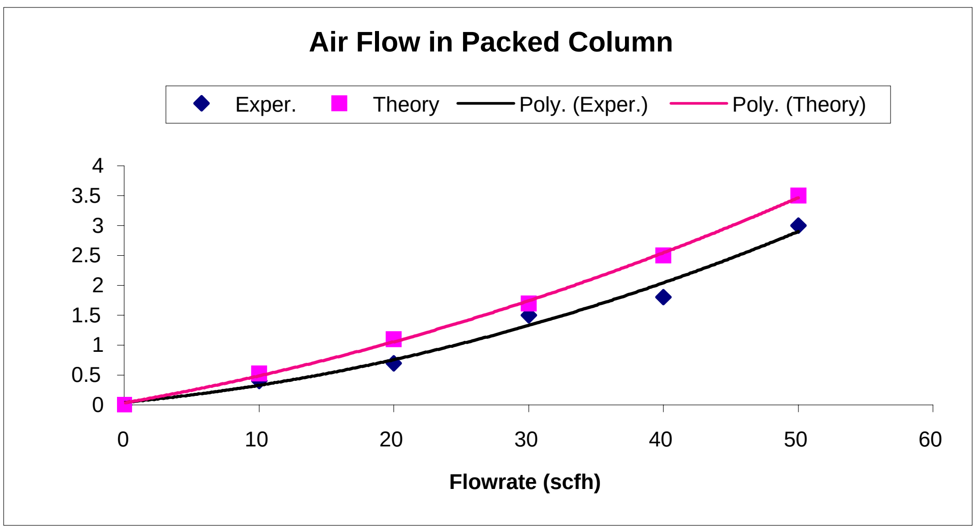
- *Microsoft Visio®* -- for drawing of schematics. Each team develops a schematic of their experimental layout.
- *Microsoft Excel®* – for calculations, and preparation of graphs and regressions. Each team plots their experimental data against theoretical values calculated within the spreadsheet. They also present calibration data as a parity plot.
- *Microsoft Word®* -- for writing of text documents. Each team prepares a memo containing a plot of data and theory, as well as the theoretical equation presented with the equation editor.
- *Microsoft PowerPoint®* -- for making oral presentation slide shows. As a capstone experience, each team presents their work and results at the end of the semester to an audience which includes the entire class, upper-level chemical engineering students, and interested faculty members.

To augment the computer experience offered in the ChE PC lab, the student teams are encouraged to bring a laptop to the lab for data entry, quick raw data analysis, and system layout sketching.

Specific Experimental / Modeling Exercises

Two exercises have been incorporated into the ChE FED course that combine experimental data collection with a priori modeling. These exercises make excellent use of Microsoft Excel®. They observe the pressure drops across 3-foot plastic PVC pipes (1” diameter) pipes packed with small plastic nylon pellets as functions of fluid flow rate. The air subsection contains one such pipe; the water subsection contains another. Students use the Ergun equation to predict the observed pressure drops across these packed pipes. While they will not be familiar with the Ergun equation and its principles until their Fluid Flow course, they still benefit from the exercise of using a theoretical relationship to simulate an experiment, as opposed to just a simple correlation. Figure 5 shows sample experimental data and Ergun modeling. Generally, the results are fairly good. The students learn an appreciation for the accuracy and precision of experimental data, as well as the sensitivity of modeling results to the values of application-specific parameters, such as those associated with the plastic pellets (e.g. void fraction).

Figure 5: Sample experimental and modeling data for packed pipe using in FED setup



Equipment Calibration and Characterization

Two exercises that are performed in the lab during or after layout construction stress the importance of equipment calibration and characterization. The first is the simple calibration of the water flow meters built into their water subsections. The results (parity plots) are plotted with Microsoft Excel®.

The second is the determination of the characteristic curve of the small centrifugal pump built into each system. House water is made available at a low, regulated feed pressure. The pressure head developed across the pump is measured as a function of flow rate. The observed characteristic curve is compared, on the same plot, with the specification curve from the manufacturer. Results are typically good.

One especially enjoyable exercise is the observation of the maximum head output at zero flow rate for the pumps. This is accomplished by requiring as a constraint that the students build an open-ended clear tube as a “tee” off of the main water flow line several feet above the level of the pump. In the experiment, the water flow is directed up the clear pipe with the pump running. The flow stops at a level corresponding to the maximum net pump head. The students measure this value with a tape measure, and compare it to the zero flow value on the characteristic curve.

Some Interesting Observations

Several important observations have been made based on anecdotal and survey data:

- Female students generally perform as well, especially mechanically, as do male students.
- Computer backgrounds of the entering students are mixed.
- The FED students enjoy the challenges presented to them, and often call for more such mechanical experiences in subsequent courses.
- Feedback indicates that the students enjoy the course very much, with many showing an improving confidence over the semester, especially with mechanical activities. Such feedback suggests that this course is a positive tool for undergraduate retention in chemical engineering and the college.
- Positive FED experiences by some undecided freshmen have resulted in their declarations of Chemical Engineering as their undergraduate majors.
- Interactions between freshmen working in the FED laboratory and visiting high school students passing through on tours has proven to be an effective recruitment device.

In Conclusion

The chemical engineering FED course has proven to be an effective introductory experience for our new students. It also serves as a good recruitment tool to attract high school students to come to NJIT. Over time, we will upgrade the FED laboratory and computer experiences as resources allow.

References

[i] *Engineering Education Coalitions-Meeting the Need for Reform*, National Science Foundation, NSF 93-58a.
[ii] See www.ABET.org
[iii] Burton, J. D. and White, D. M., *Journal of Engineering Education*, July (1999).